



**US Army Corps  
of Engineers**  
Waterways Experiment  
Station

Technical Report HL-96-6  
August 1996

# **Petaluma River, Channel Constriction Project, Sonoma County, California**

## **Hydraulic Model Investigation**

*by Billy D. Fuller*

Approved For Public Release; Distribution Is Unlimited

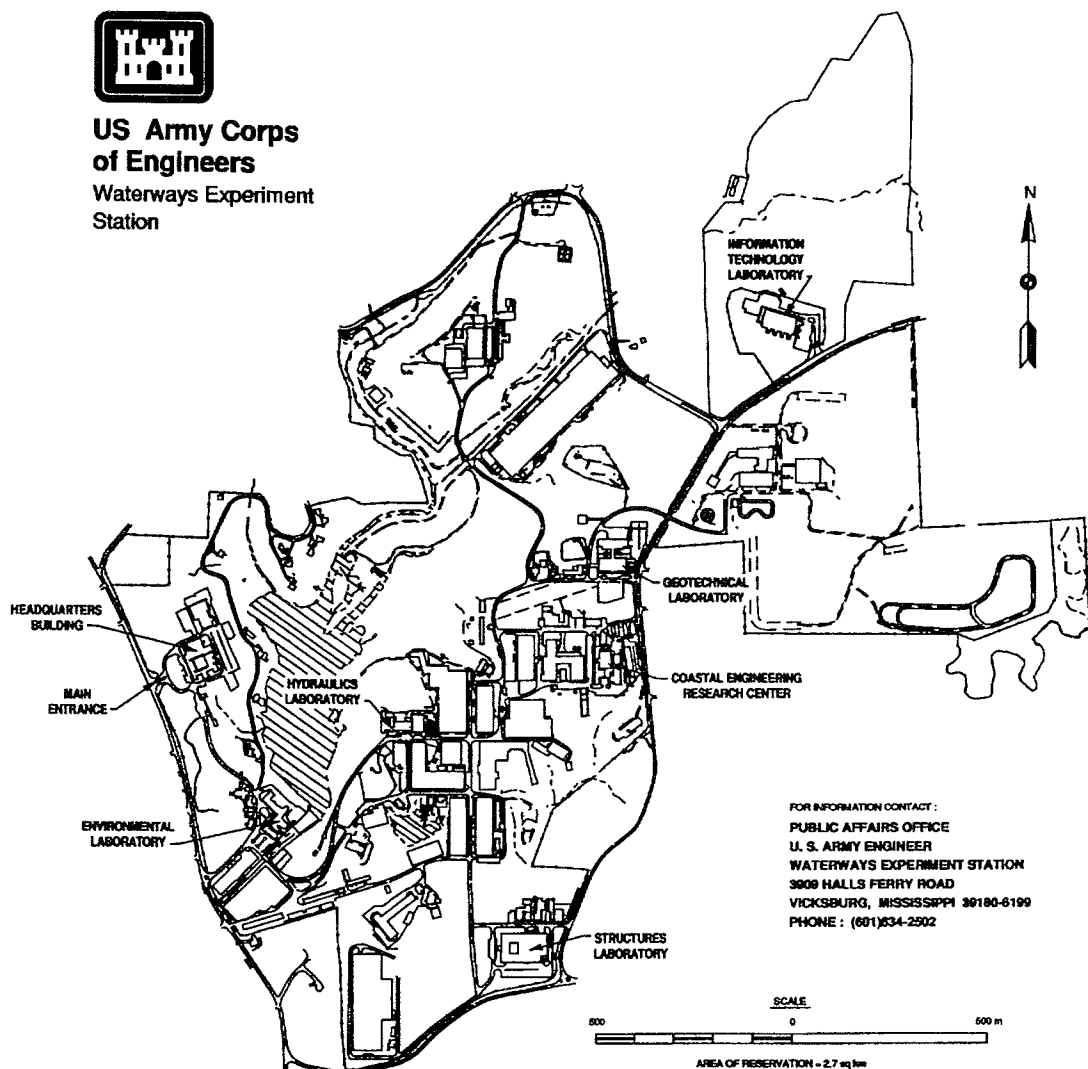
The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.



PRINTED ON RECYCLED PAPER



**US Army Corps  
of Engineers**  
Waterways Experiment  
Station



**Waterways Experiment Station Cataloging-in-Publication Data**

Fuller, Billy D.

Petaluma River Channel Constriction Project, Sonoma County, California,  
hydraulic model investigation / by Billy D. Fuller ; prepared for U.S. Army  
Engineer District, San Francisco.

48 p. : ill. ; 28 cm. — (Technical report ; HL-96-6)

Includes bibliographical references.

1. Petaluma River (Calif.) 2. Channels (Hydraulic engineering) — Califor-  
nia — Petaluma River. 3. Weirs — California — Petaluma River. I. United  
States. Army. Corps of Engineers. San Francisco District. II. U.S. Army Engineer  
Waterways Experiment Station. III. Hydraulics Laboratory (U.S. Army Engineer  
Waterways Experiment Station) IV. Title. V. Series: Technical report (U.S. Army  
Engineer Waterways Experiment Station) ; HL-96-6.

TA7 W34 no.HL-96-6

# Contents

---

Preface . . . . .	iv
1—Introduction . . . . .	1
Prototype . . . . .	1
Purpose of Model Study . . . . .	1
2—Model . . . . .	2
Description . . . . .	2
Scale Relations . . . . .	2
3—Experiments and Results . . . . .	4
Riprap Protection Blanket . . . . .	4
Weir Design . . . . .	4
4—Conclusions . . . . .	6
Figures 1-11	
Tables 1-2	
Photos 1-4	
Plates 1-17	
SF 298	

# Preface

---

The model investigation reported herein was authorized by the District Commander, U.S. Army Engineer District, San Francisco, 18 April 1995.

The study was conducted by personnel of the Hydraulics Laboratory (HL), U.S. Army Engineer Waterways Experiment Station (WES), during the period April to September 1995. The study was conducted under the direction of Messrs. R. A. Sager, acting Director; R. F. Athow, acting Assistant Director; and J. F. George, acting Chief, Hydraulic Structures Division (HSD). The experiments were conducted by Messrs. D. White, T. Jackson, and B. D. Fuller, Spillways and Channels Branch, HSD, under the supervision of Mr. B. P. Fletcher, Chief of the Spillways and Channels Branch. This report was prepared by Mr. Fuller.

The constriction weir was constructed by Messrs. J. Schultz and J. Jeffreys, Engineering and Construction Services Division (E&CSD), under the supervision of Mr. Ed A. Case, E&CSD. The channel contours were prepared by personnel of the Construction Services Division under the supervision of Mr. Michael B. Sims, E&CSD.

During the course of the investigation, Mr. Carlos Hernandez, Ms. Jerri Kasemsant, and Mr. Bill Firth, U.S. Army Engineer District, San Francisco, visited WES to observe model operation, discuss experiment results, and correlate these results with concurrent design work.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

*The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.*

# 1 Introduction

---

## Prototype

The proposed structure will be located approximately 64 km (40 miles) north of San Francisco, in the city of Petaluma, CA (Figure 1). Channel improvements are proposed for the stretch of the Petaluma River shown in Figure 2. These improvements will improve the flow conditions of the river in this region. To prevent lowering water-surface elevations and increasing flow velocities in the regions just above the project stretch, a constriction weir was proposed.

The proposed channel constriction is designed to maintain preproject water-surface elevations and flow velocities upstream of the improved channel. The preliminary design for this constriction weir was provided by the U.S. Army Engineer District, San Francisco, and based on the Corps' HEC-2 algorithm.

## Purpose of Model Study

The model study was conducted to validate the preliminary design of the constriction weir or modify the weir dimensions as necessary to provide the desired upstream water-surface elevations. Another purpose for this study was to determine if the riprap protection blanket was adequately sized. The proposed blanket (type 1) extended 7.6 m (25 ft) upstream and downstream of the constriction weir and was 0.7 m (27 in.) thick.

## 2 Model

---

### Description

This 1:10-scale (Figure 3) model was installed in a portion of an existing flume that permitted simulation of the constriction weir and 30 m (100 ft) of upstream and downstream topography from the weir.

The constriction weir (Plate 1) was constructed of plywood to allow easy modification. Modifications of the constriction weir opening and height were made to adjust head loss to achieve the desired upstream water-surface elevations. An isometric view of the approach and exit channels and the constriction weir is shown in Plate 2. Photographs of the model are shown in Figures 4 through 7.

The upstream and downstream riverbeds were molded to the proposed cross section profiles (Plate 3) by using sheet metal templates.

Riprap protection initially proposed consisted of a 0.7-m- (27-in.) thick blanket that extended 7.6 m (25 ft) upstream and downstream from the weir. The riprap protection consisted of crushed limestone with a  $D_{100}$  of 0.7 m (27 in.) (Plate 4).

Flow through the model was recirculated using variable velocity pumps, and discharges were measured by use of a calibrated weir. Water-surface elevations were measured with point gauges at the locations coinciding with HEC-2 nodal points. These locations were in the center of the channel, 7.6 m (25 ft) downstream and 15 m (50 ft) upstream of the constriction weir. Velocities were measured with paddle wheel flow meters. Tailwater elevations were maintained by use of an adjustable tailgate.

### Scale Relations

The accepted equations of hydraulic similitude, based on the Froudian criteria, were used to express mathematical relations between the dimensions

and hydraulic quantities of the model and prototype. General relations for the transference of model data to prototype equivalents are as follows:

Characteristics	Dimensions <sup>1</sup>	Scale Relations Model:Prototype
Length	$L_r$	1:10
Area	$A_r = L_r^2$	1:100
Velocity	$V_r = L_r^{1/2}$	1:3.1623
Discharge	$Q_r = L_r^{5/2}$	1:316.23
Volume	$V_r = L_r^3$	1:1000
Weight	$W_r = L_r^3$	1:1000
Time	$T_r = L_r^{1/2}$	1:3.1623
<sup>1</sup> Dimensions are in terms of length.		

Model measurements of discharge, water-surface elevations, and velocities can be transferred quantitatively to prototype equivalents by means of the scaled relations.



## 3 Experiments and Results

---

### Riprap Protection Blanket

Hydraulic conditions evaluated in this investigation are provided in Table 1. Initial investigations consisted of evaluating the stability of the proposed riprap protection. The proposed riprap protection blanket (type 1, Plate 5) consisted of riprap  $D_{100} = 0.7$  m (27 in.) extending 7.6 m (25 ft) upstream and 7.6 m (25 ft) downstream of the constriction weir. This protection blanket, when evaluated with the 2-year event, was undermined at the downstream end of the riprap blanket as the model bed material (sand) scoured (Photos 1 through 4).

The downstream end of the riprap blanket was extended to 30 m (100 ft) (type 2 design). A drawing of the type 2 design riprap is shown in Plate 6, and photographs are provided in Figures 8 through 11. The results indicated that the type 2 design riprap plan provided satisfactory protection for the modeled channel for all anticipated flow conditions. It was determined that velocity data should be taken with each flow condition to allow further investigation of possible scouring. The magnitude and direction of current velocities for the type 2 design riprap protection plan with 2-, 10-, 40-, and 100-year events are provided in Plates 7 through 10.

### Weir Design

Experiments were then conducted to determine the head loss over the weir for various flow conditions. An experiment consisted of setting the discharge and tailwater elevation, allowing time for the flow to stabilize, and recording the pool elevation. The data from evaluation of the original weir design (type 1) are tabulated in Table 2, which shows a comparison of the measured (model) water-surface elevations with computed values. If the measured water-surface differential equals or minimally exceeds the computed values, the weir design was considered satisfactory. As can be seen in Table 2, the type 1 weir did not provide sufficient head loss for the 10-, 40, and 100-year events.

The length of the upper notch of the weir was reduced from 14.6 (48) to 12.4 m (40.8 ft) to increase the head loss across the weir. This was designated the type 2 design weir, as shown in Plate 11. The water-surface elevations for the 10- and 40-year events are presented in Table 2. These data indicated that the type 2 design weir satisfied the 10-year event but provided only limited improvements for the 40-year event.

To further increase the head loss, the weir was modified by raising the top of the constriction weir from el 13.0 to 14.2.<sup>1</sup> This was designated the type 3 design weir and is shown in Plate 12. The data associated with this design indicated that unsatisfactory results were obtained with the 40-year event (Table 2).

The weir was again modified in an attempt to improve the hydraulic performance of the weir for the full range of flow events. The top of the weir was raised to el 15.0, which is the highest practical elevation in the prototype. Also, by raising the weir to el 15.0, this increased the width of the weir from 12.4 to 13.0 m (40.8 to 42.8 ft) (type 4 design weir, Plate 13). Satisfactory results were obtained for the 2-, 10-, 40-, and 100-year flow events, as shown in Table 2. Although the measured water-surface differential for the 40-year event did not exceed the predicted, the type 4 design weir was accepted, since overbank topography made it impractical to raise the top of the weir above el 15.0. Additional investigation indicated that the type 2 design riprap protection plan was stable for all anticipated flows with the type 4 design constriction weir. The magnitude and direction of current velocities with these designs are shown in Plates 14 through 17.

---

<sup>1</sup> Unless stated otherwise, all elevations (el) cited herein are in feet as referred to in the National Geodetic Vertical Datum (NGVD) of 1929. To convert elevations to meters, multiply by 0.3048.

## 4 Conclusions

---

Experimental results indicated a riprap protection blanket with a  $D_{100}$  of 0.7 m (27 in.), extending 7.6 m (25 ft) upstream and 30 m (100 ft) downstream from the constriction weir and providing adequate erosion protection in the modeled channel. This final design (type 2) is shown in Plate 6. Additional information, velocity magnitudes, and directions were recorded to provide an indication to design engineers as to the erosion potential of the material downstream of the modeled channel.

The final weir design (type 4, Plate 13) provided adequate head loss through the weir. These data are presented in Table 2. Although the measured water-surface differential for the 40-year event did not exceed the predicted, the type 4 design weir was accepted since the top of the weir could not be raised above el 15.0. Further constriction of the notches would raise upstream water-surface elevations and increase velocities downstream for the 2- and 10-year events.

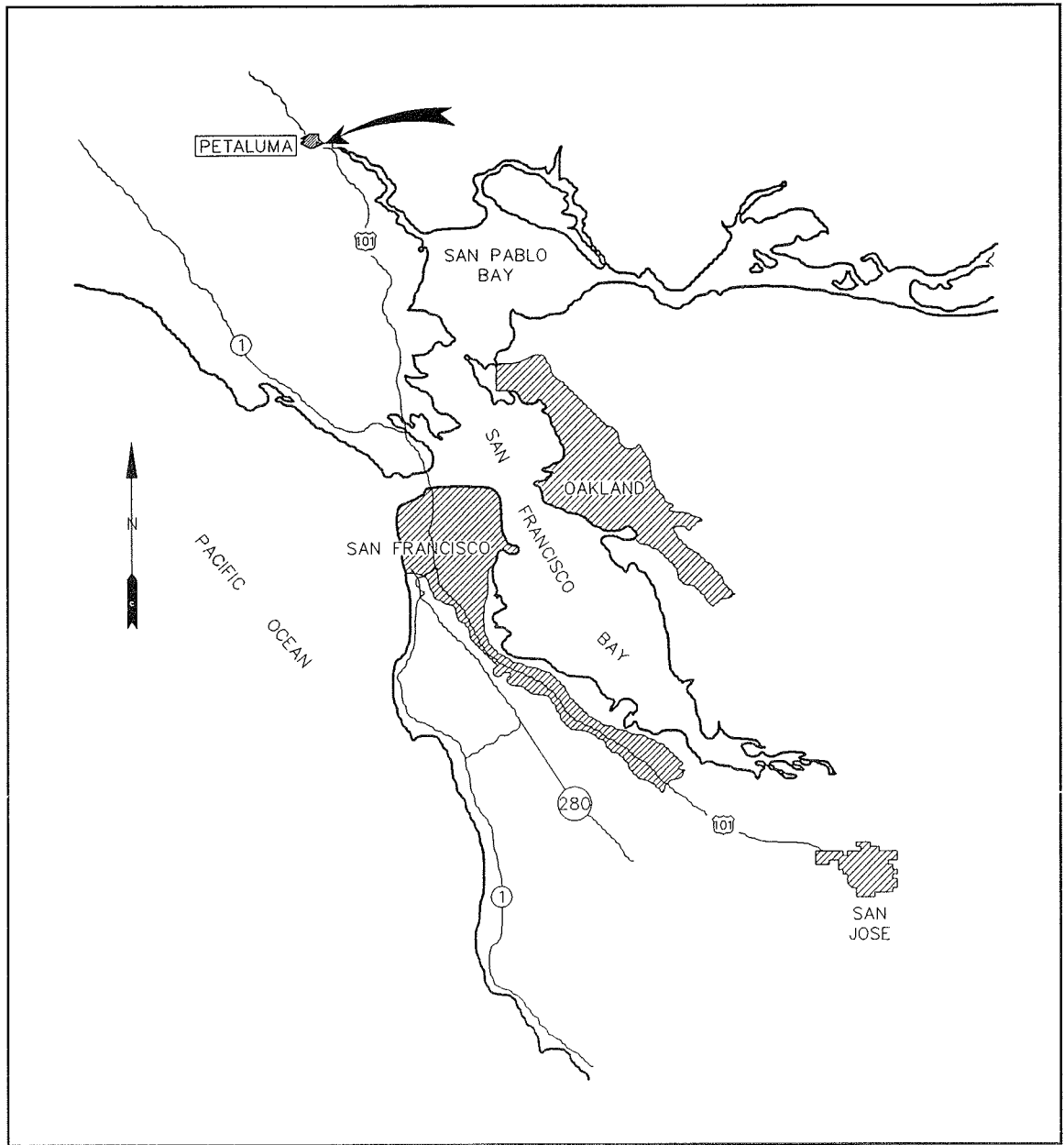


Figure 1. Vicinity map

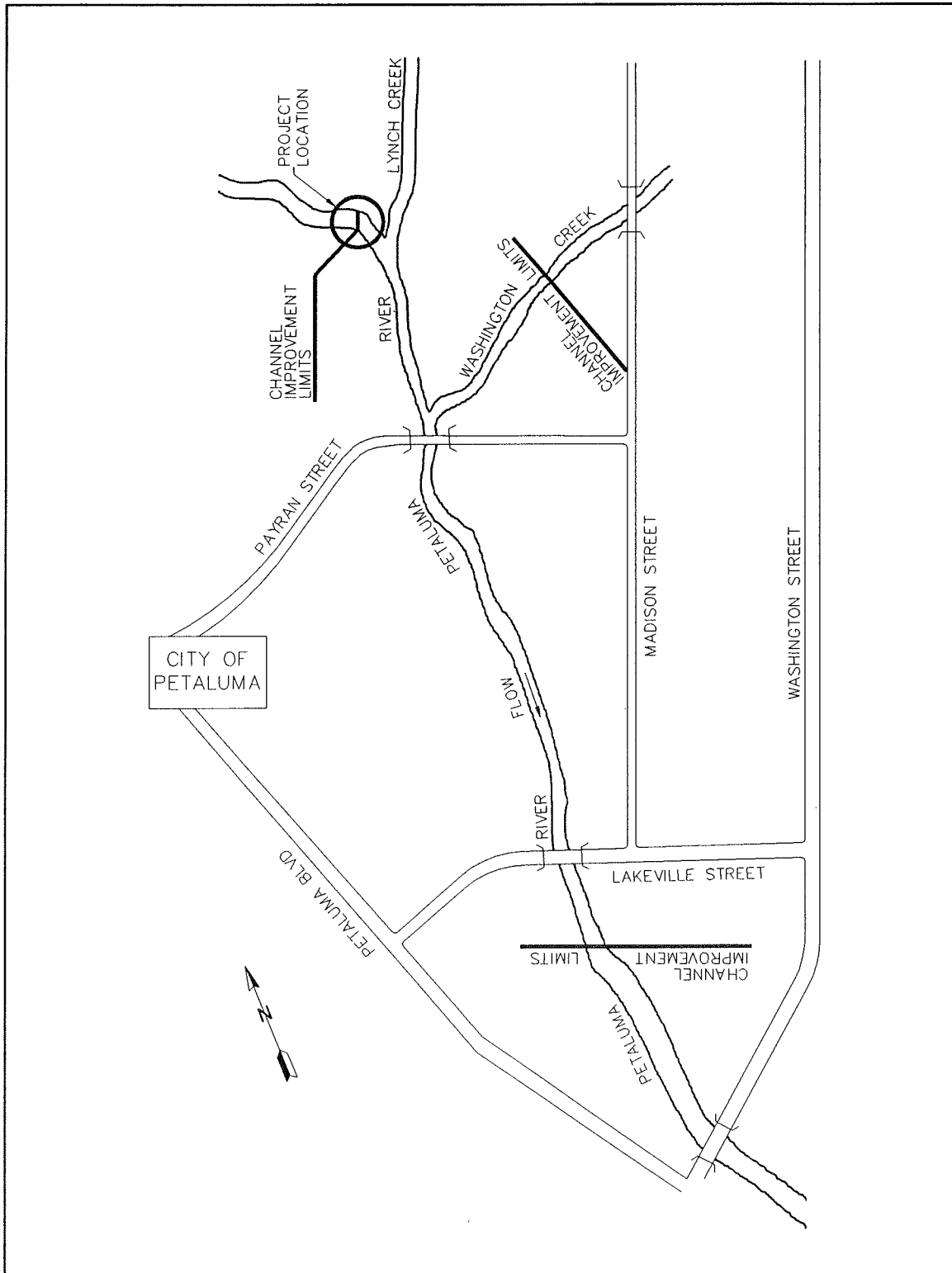


Figure 2. Location map

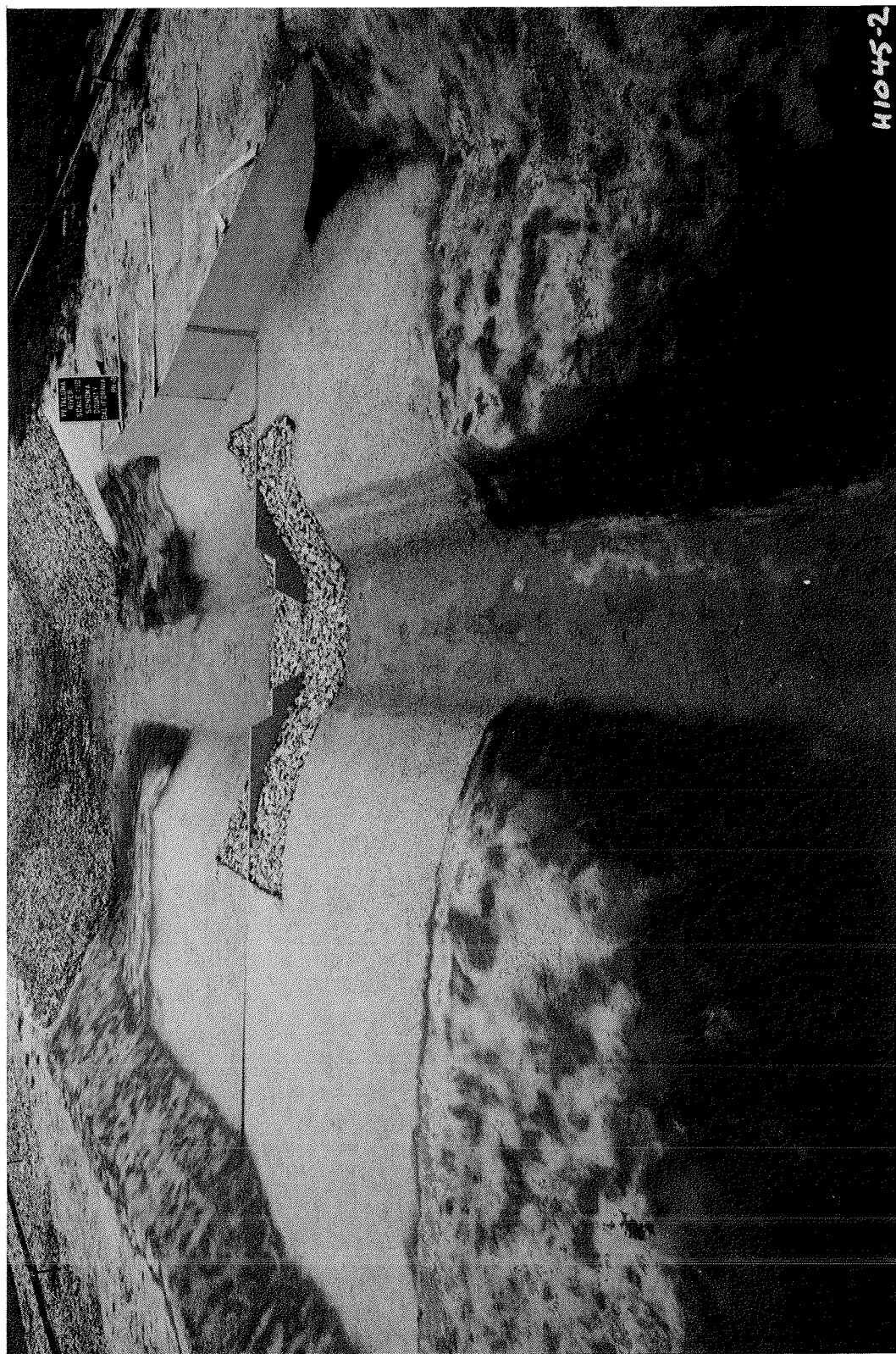
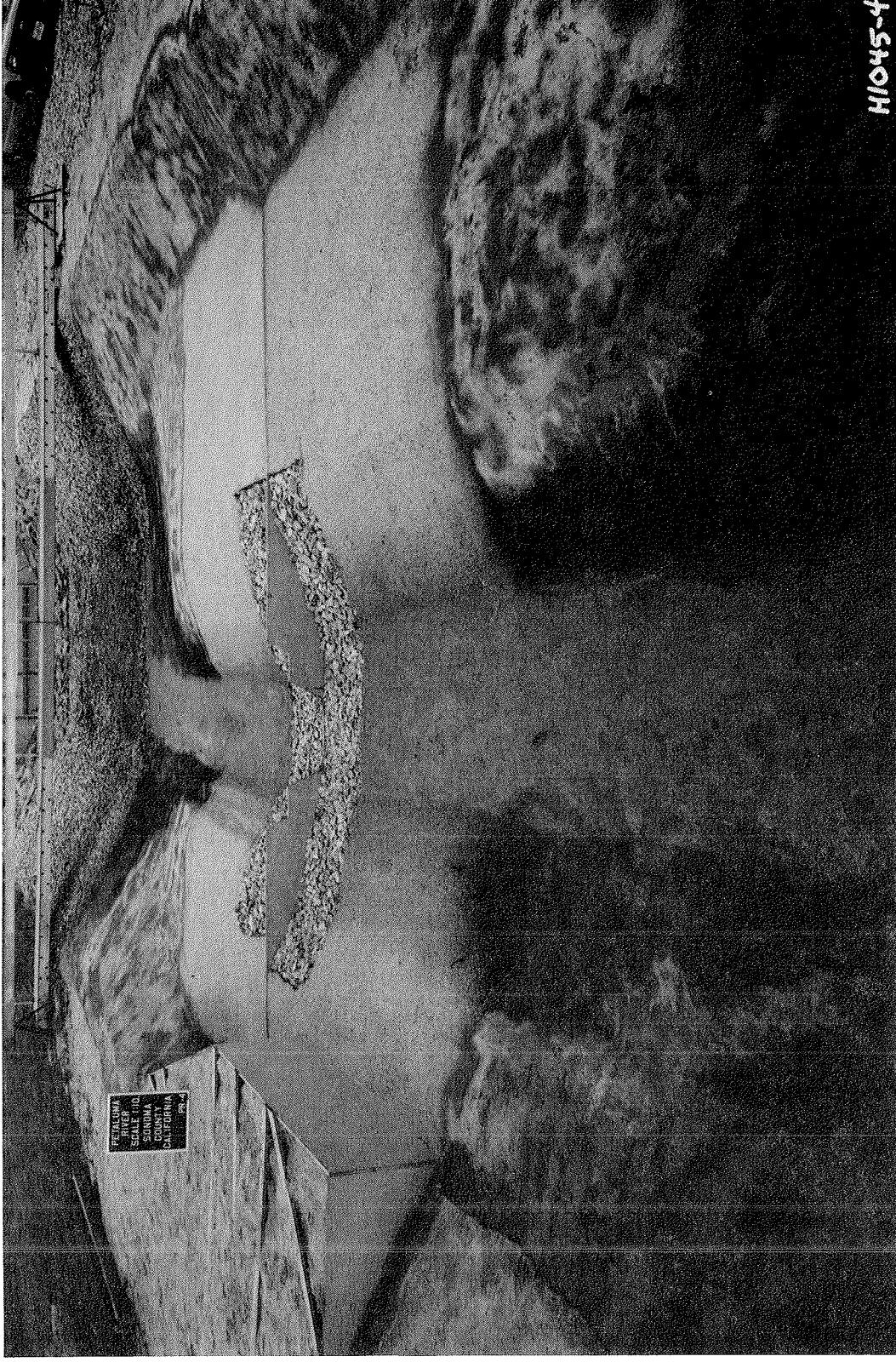


Figure 3. The 1:10-scale model, downstream view



H1045-4

Figure 4. Upstream view of weir





Figure 5. Side view of weir



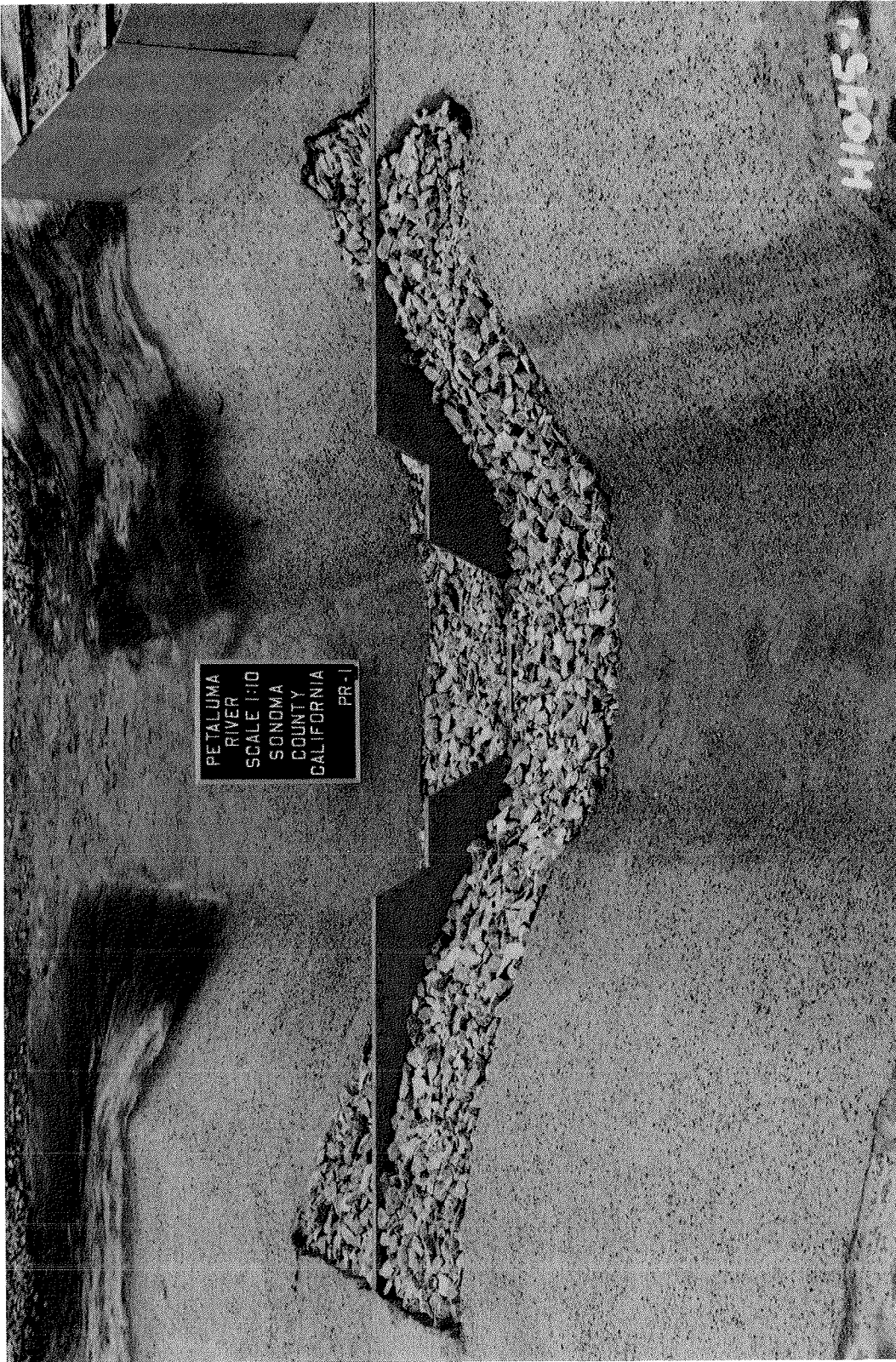


Figure 6. Downstream view of weir

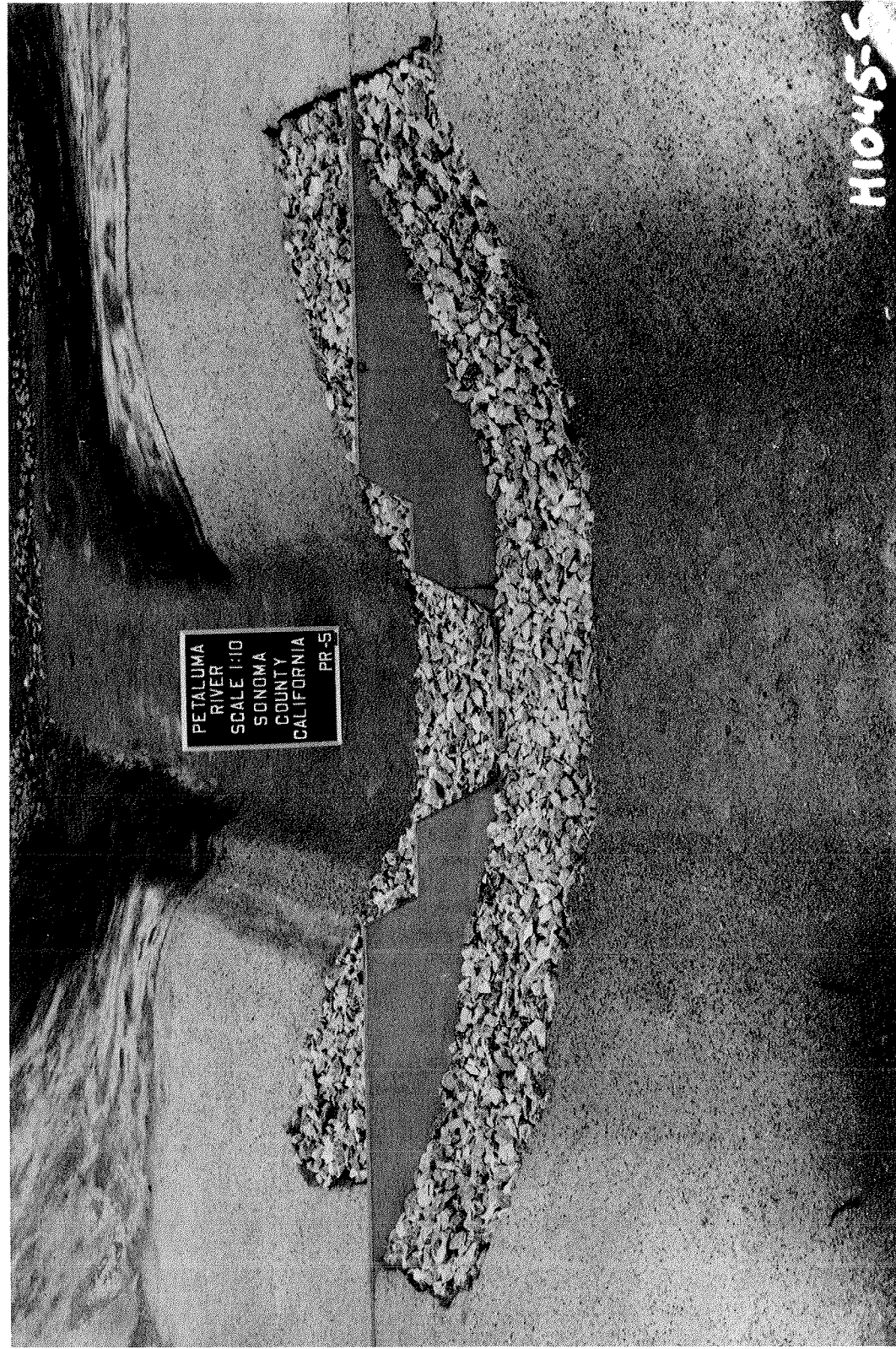


Figure 7. View of weir, upstream





Figure 8. Type 2 riprap design, downstream general view

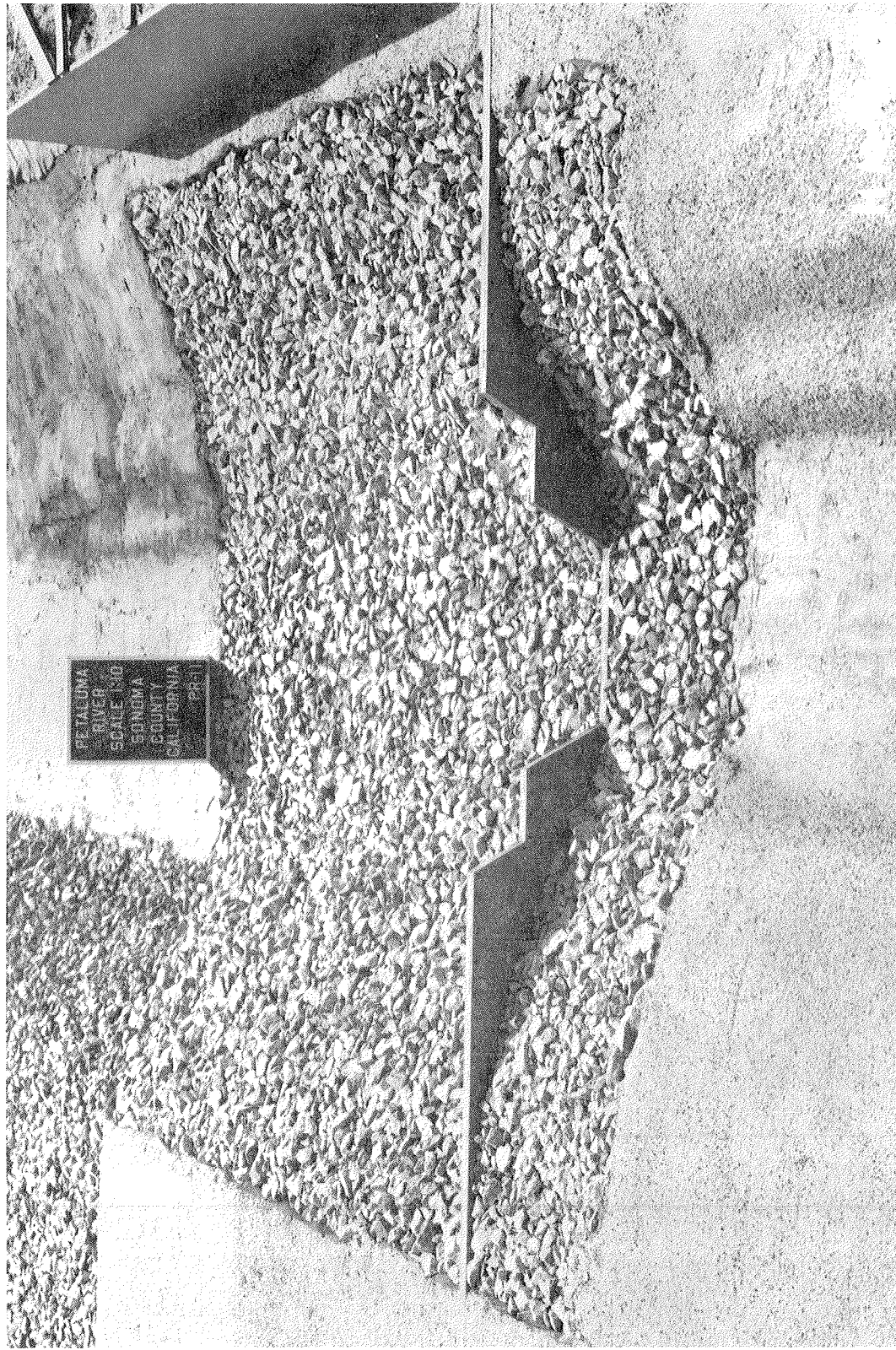


Figure 9. Type 2 riprap design, downstream view





Figure 10. Type 2 riprap design, side view



Figure 11. Type 2 riprap design, upstream view

Table 1 Hydraulic Conditions				
Event, Years	Discharge		Headwater El, ft	Tailwater El, ft
	cfs	m <sup>3</sup> /sec		
2	1,150	32.6	6.88	5.99
10	3,740	105.9	13.71	11.39
40	7,070	200.2	17.66	15.25
100	8,860	250.9	18.37	17.39

Table 2 Weir Designs, Types 1, 2, 3, and 4								
Event, Years	Discharge		Measured			Computed		
	cfs	m³/sec	Tailwater El, ft	Headwater El, ft	Difference, ft	Tailwater El, ft	Headwater El, ft	Difference, ft
Original (Type 1)								
2	1,150	32.6	5.82	6.97	1.15	5.99	6.88	0.89
10	3,740	105.9	11.42	13.12	1.70	11.39	13.71	2.32
40	7,070	200.2	15.33	16.31	0.98	15.25	17.66	2.41
100	8,860	250.9	17.40	18.16	0.76	17.39	18.37	0.98
Type 2								
2	1,150	32.6	Not Tested			5.99	6.88	0.89
10	3,740	105.9	11.42	13.77	2.35	11.39	13.71	2.32
40	7,070	200.2	15.32	16.47	1.15	15.25	17.66	2.41
100	8,860	250.9	Not Tested			17.39	18.37	0.98
Type 3								
2	1,150	32.6	Not Tested			5.99	6.88	0.89
10	3,740	105.9	Note Tested			11.39	13.71	2.23
40	7,070	200.2	15.32	17.02	1.70	15.25	17.66	2.41
100	8,860	250.9	Not Tested			17.39	18.37	0.98
Type 4								
2	1,150	32.6	5.82	7.07	1.25	5.99	6.88	0.89
10	3,740	105.9	11.42	13.77	2.35	11.39	13.71	2.32
40	7,070	200.2	15.32	17.42	2.10	15.25	17.66	2.41
100	8,860	250.9	17.40	18.67	1.25	17.39	18.37	0.98



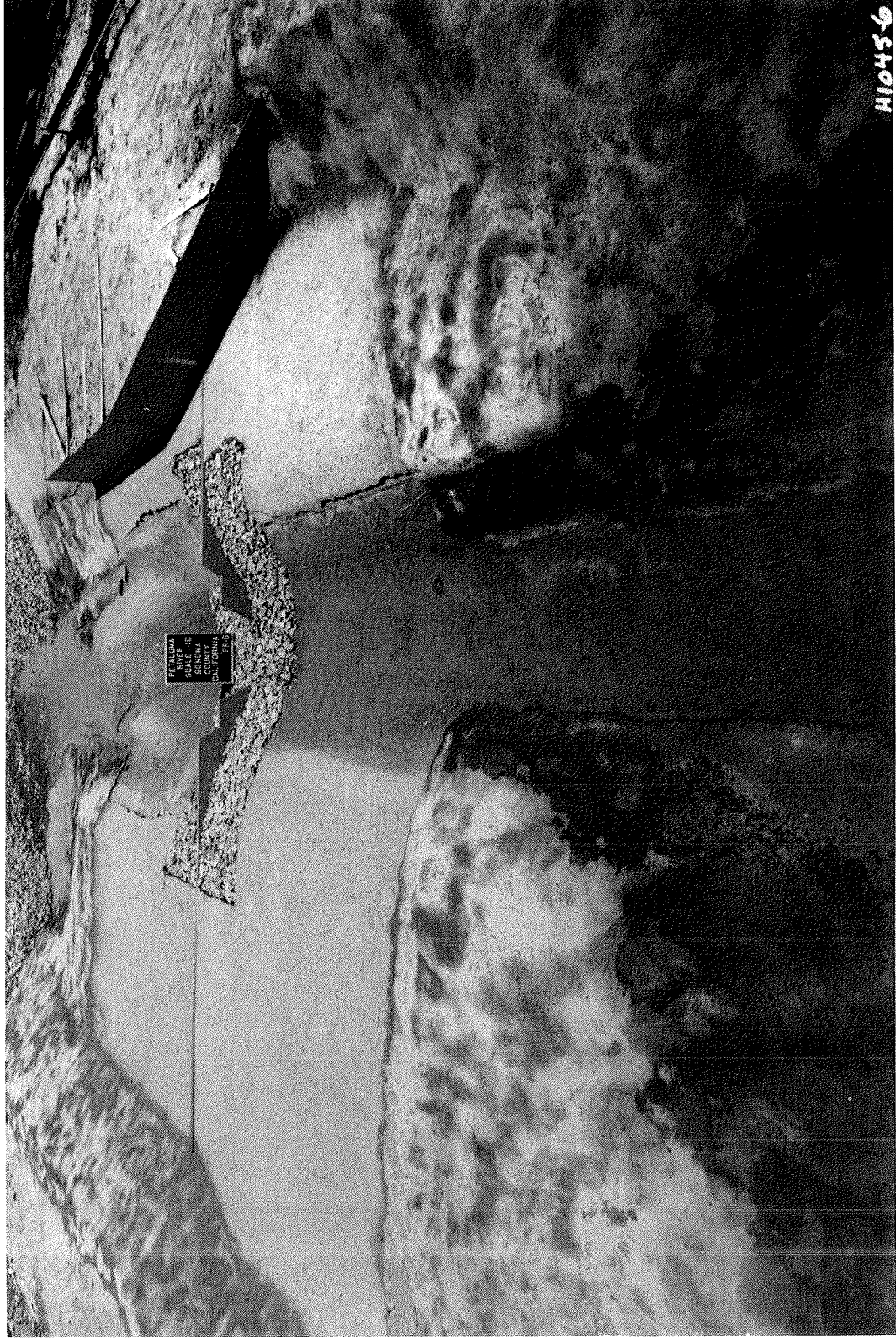


Photo 1. Riprap failure, downstream general view; discharge 350.5 m<sup>3</sup>/sec (1,150 cfs); headwater el 2.10 m (6.88 ft); tailwater el 1.83 m (5.99 ft)





Photo 2. Riprap failure, downstream view; same flow conditions as shown in Photo 1



Photo 3. Riprap failure, upstream general view; same flow conditions as shown in Photo 1



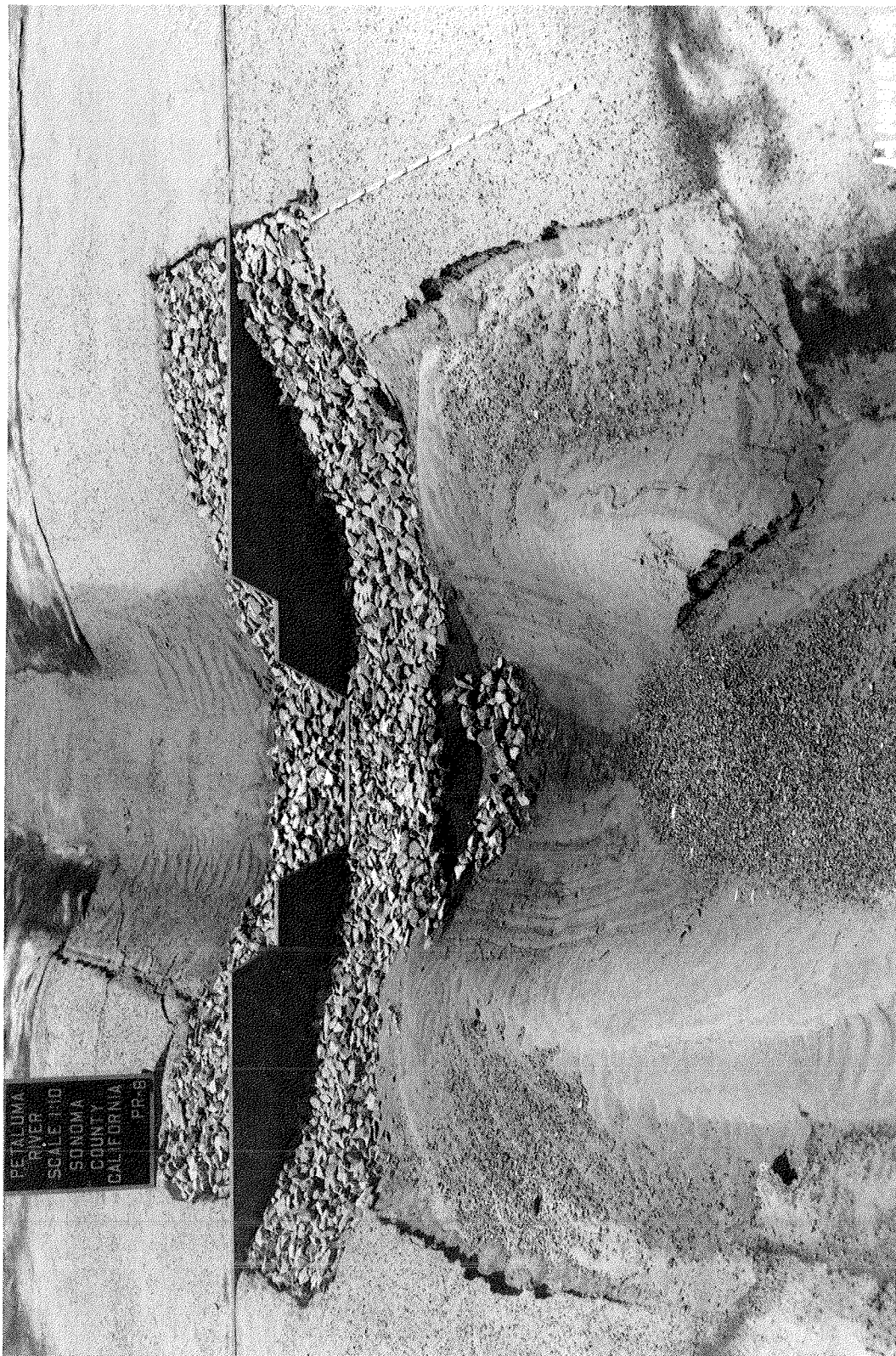


Photo 4. Riprap failure, upstream view; same flow conditions as shown in Photo 1

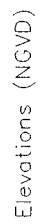
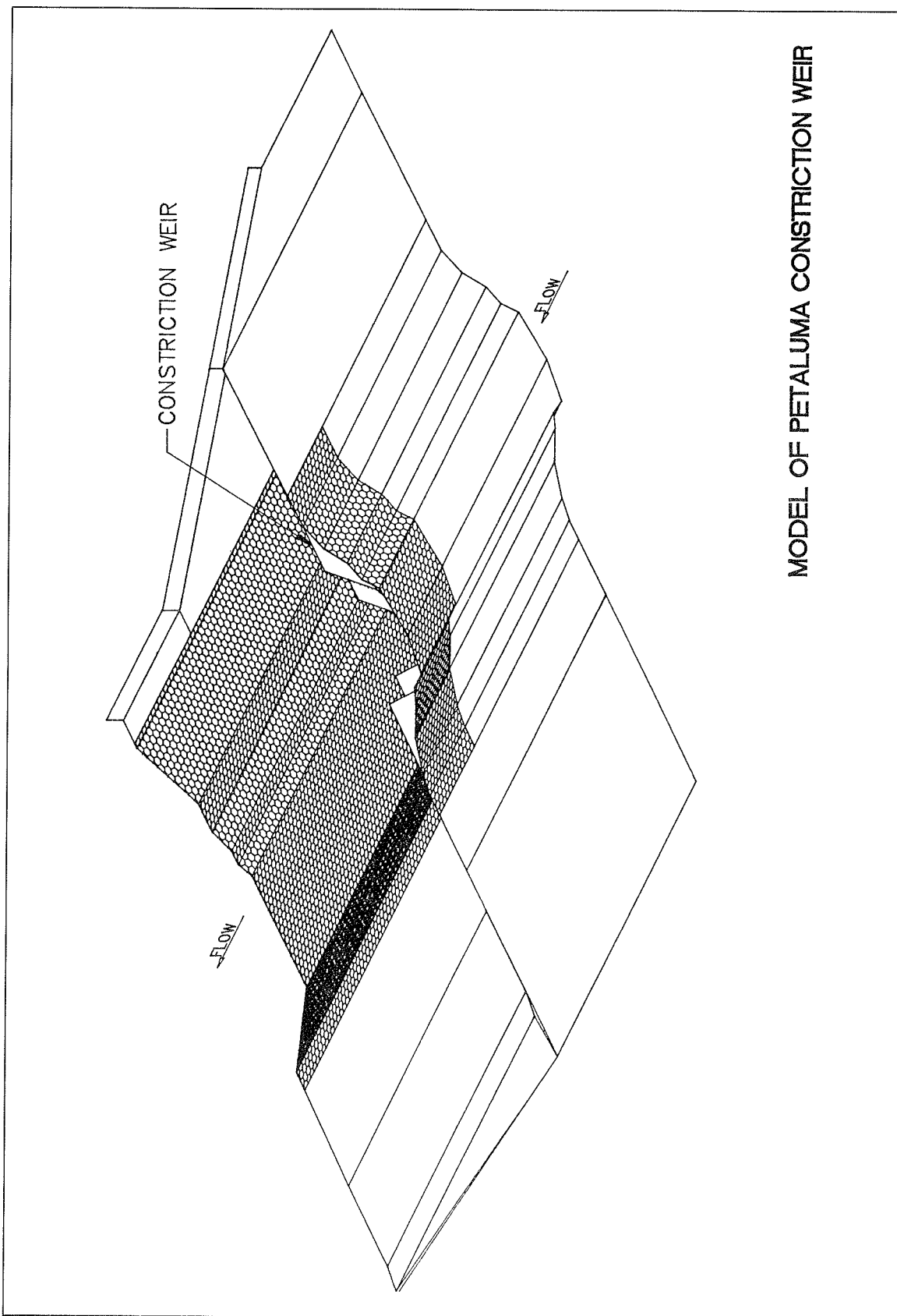
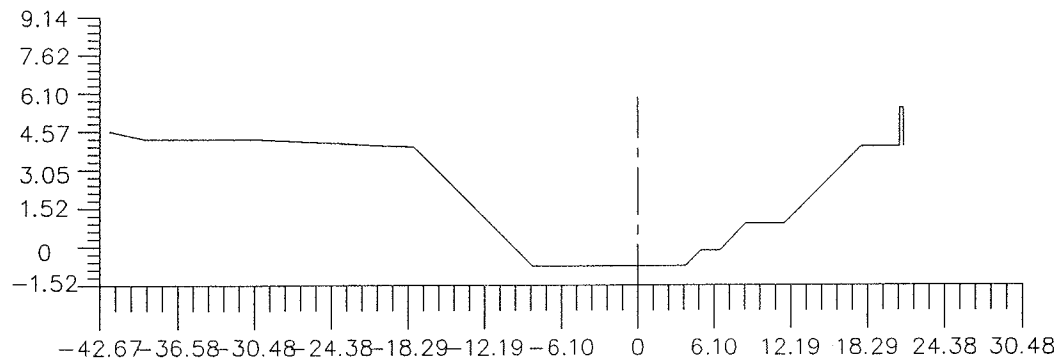


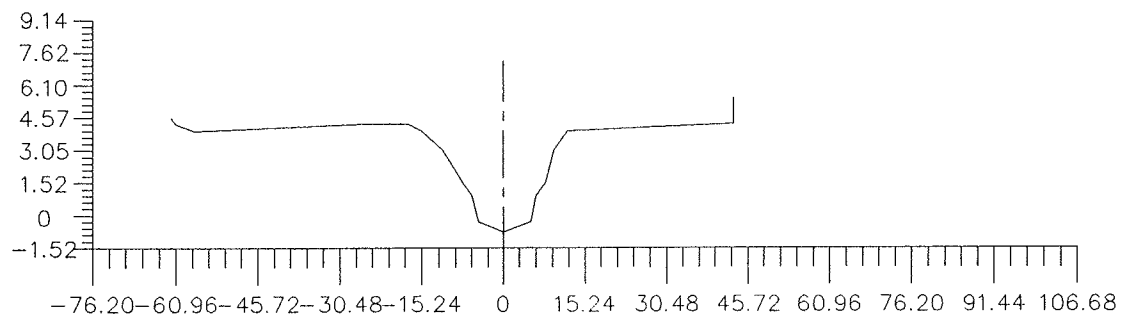
Plate 1



MODEL OF PETALUMA CONSTRICTION WEIR



SECTION A-A



SECTION B-B

Note: Sections are from Plates 5 and 6.  
Dimensions are in meters.

PETALUMA  
SECTIONS UPSTREAM AND DOWNSTREAM  
OF CONSTRICTION WEIR

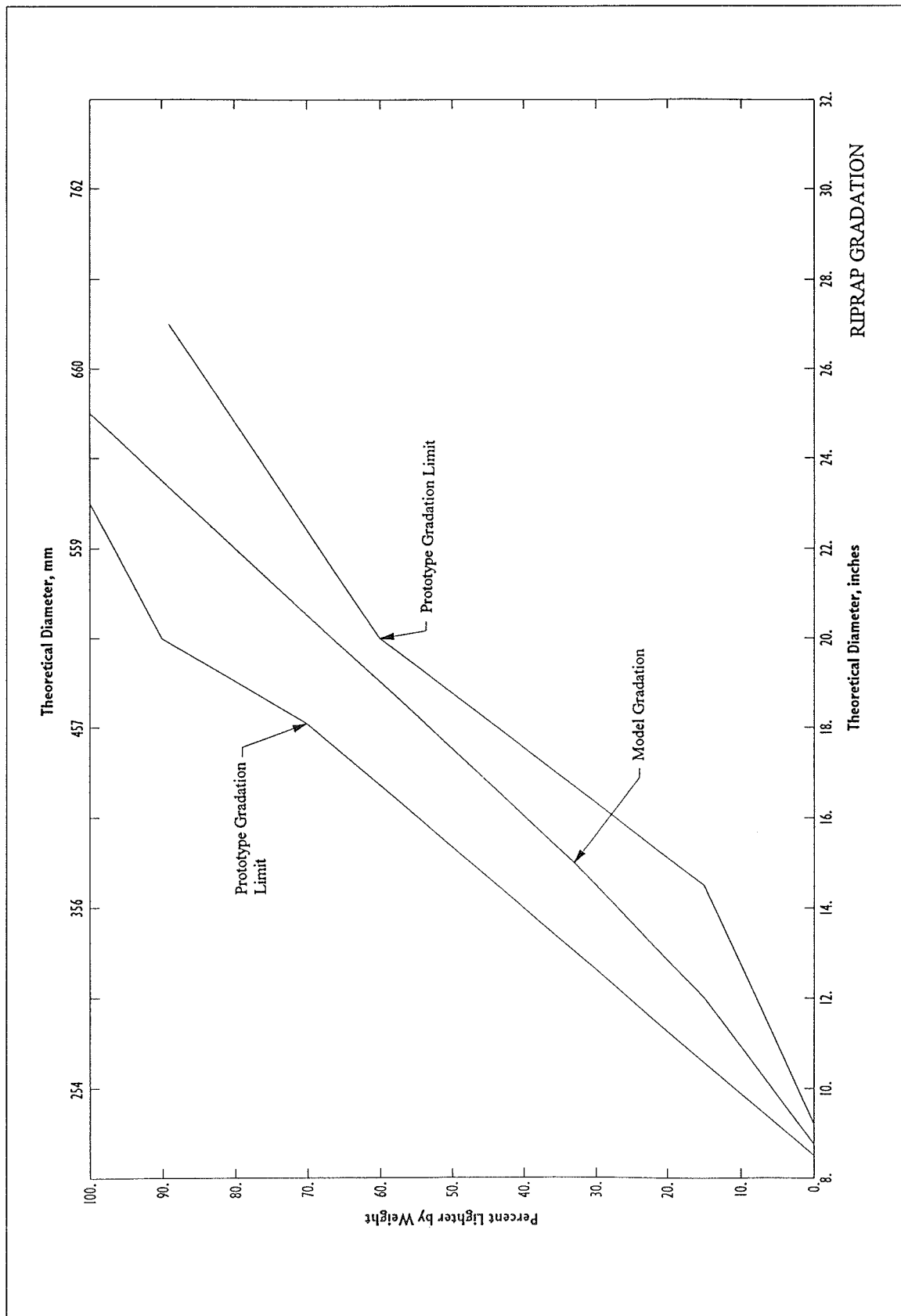
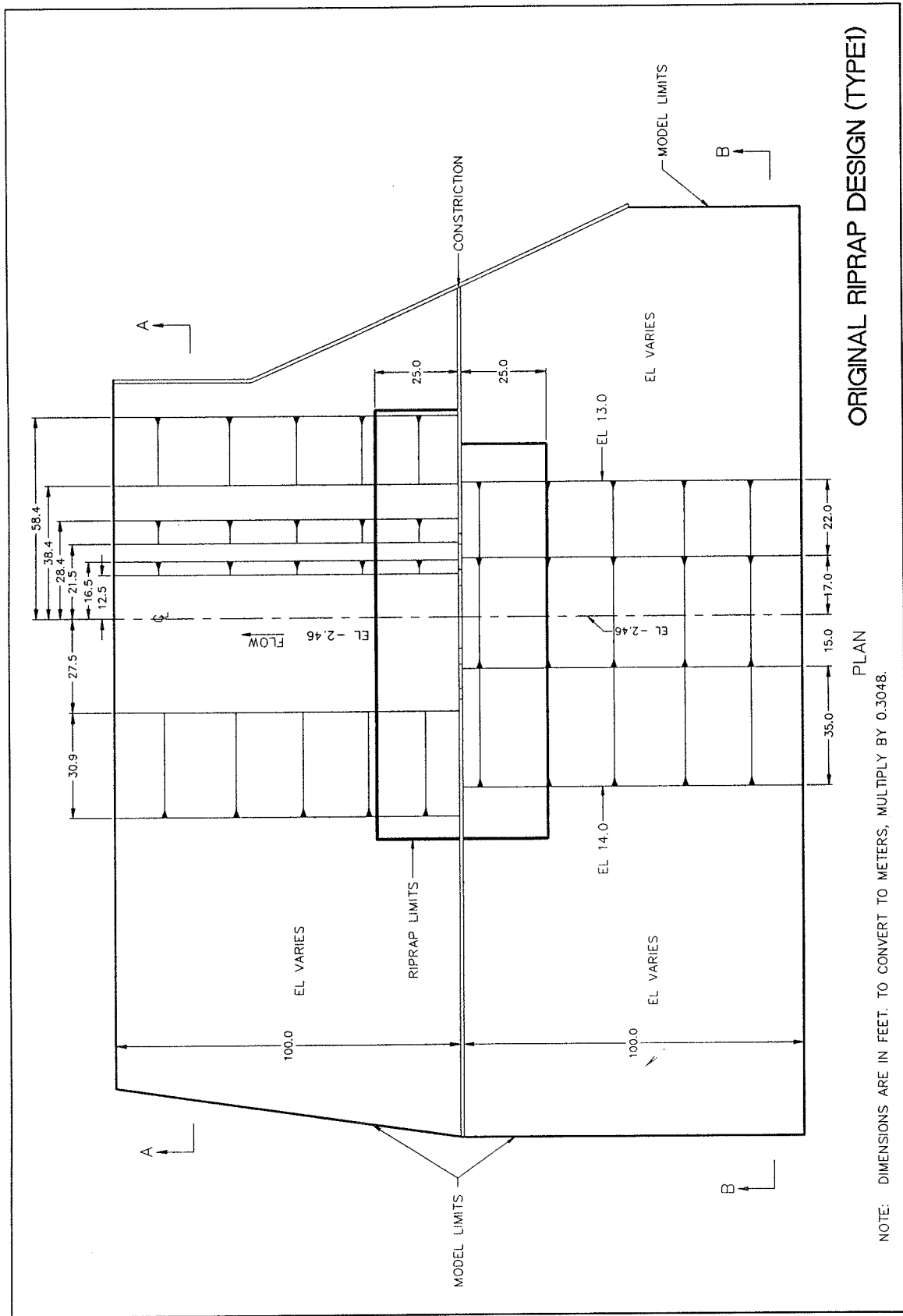


Plate 4



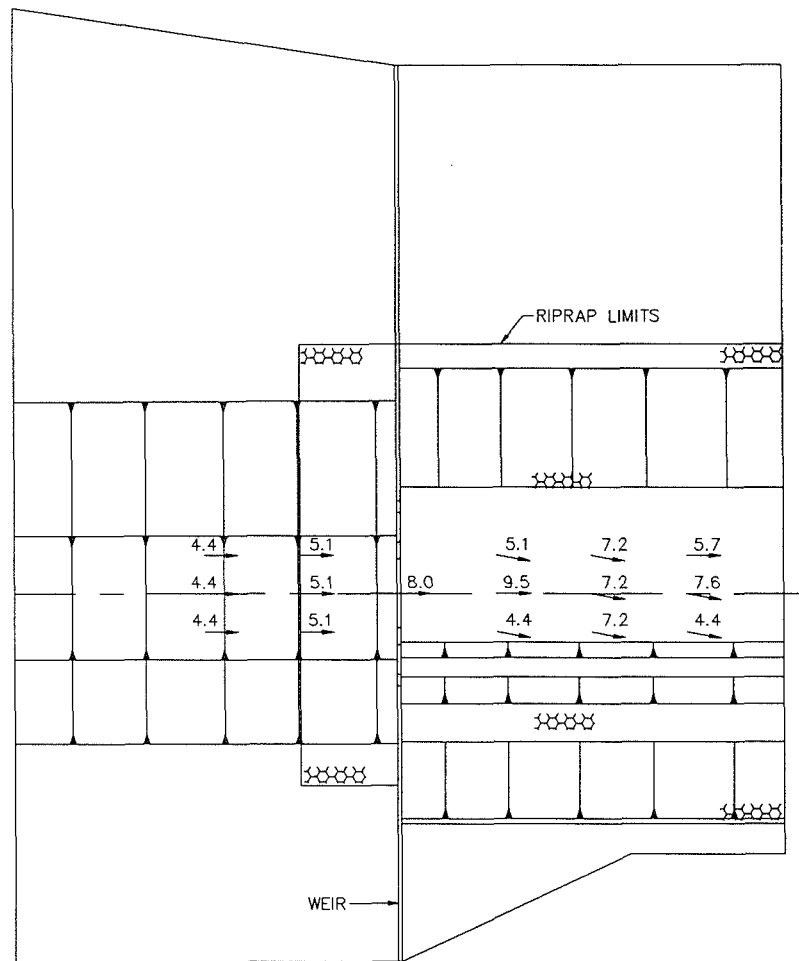




## TYPE 2 RIPRAP DESIGN

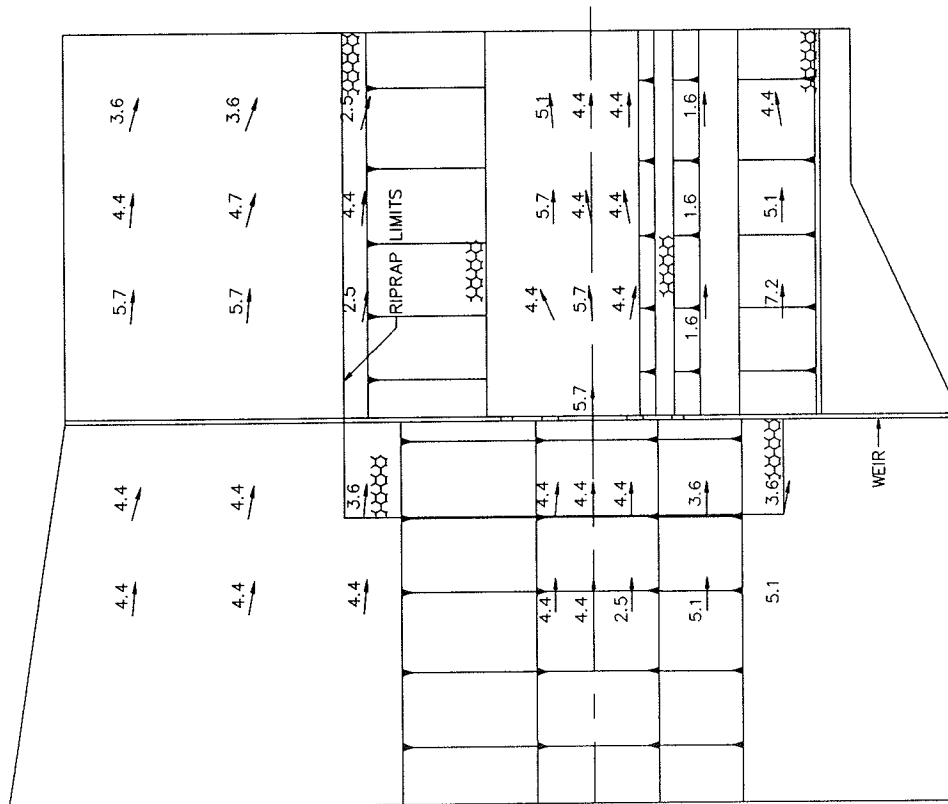


ABOVE  
0.3048



NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

TYPE 1 WEIR DESIGN  
TYPE 2 RIPRAP DESIGN  
10 YEAR EVENT

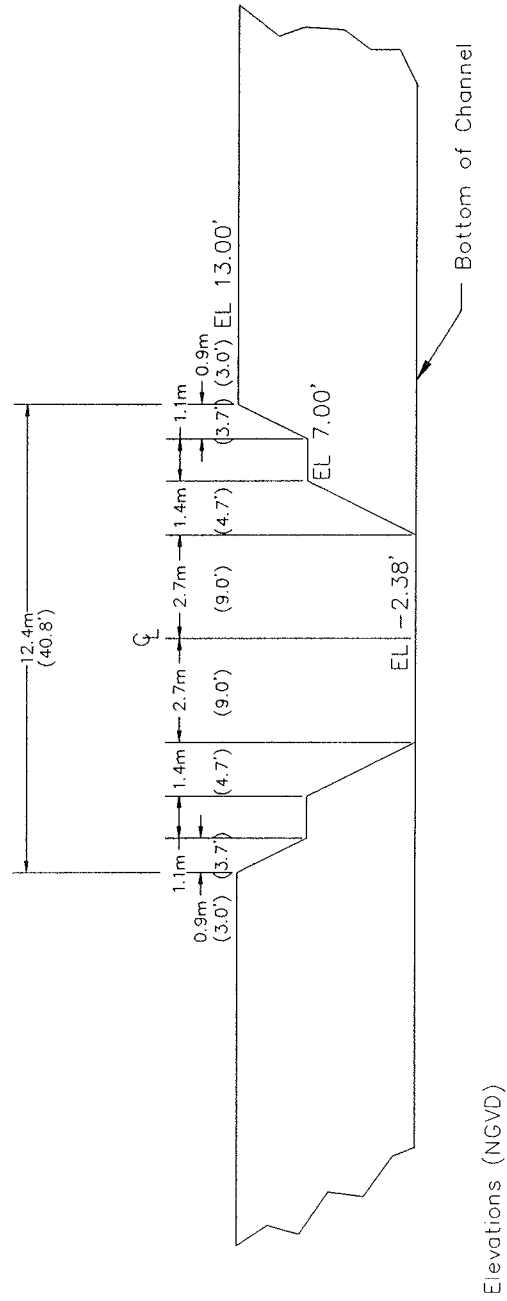


TYPE 1 WEIR DESIGN  
 TYPE 2 RIPRAP DESIGN  
 40 YEAR EVENT

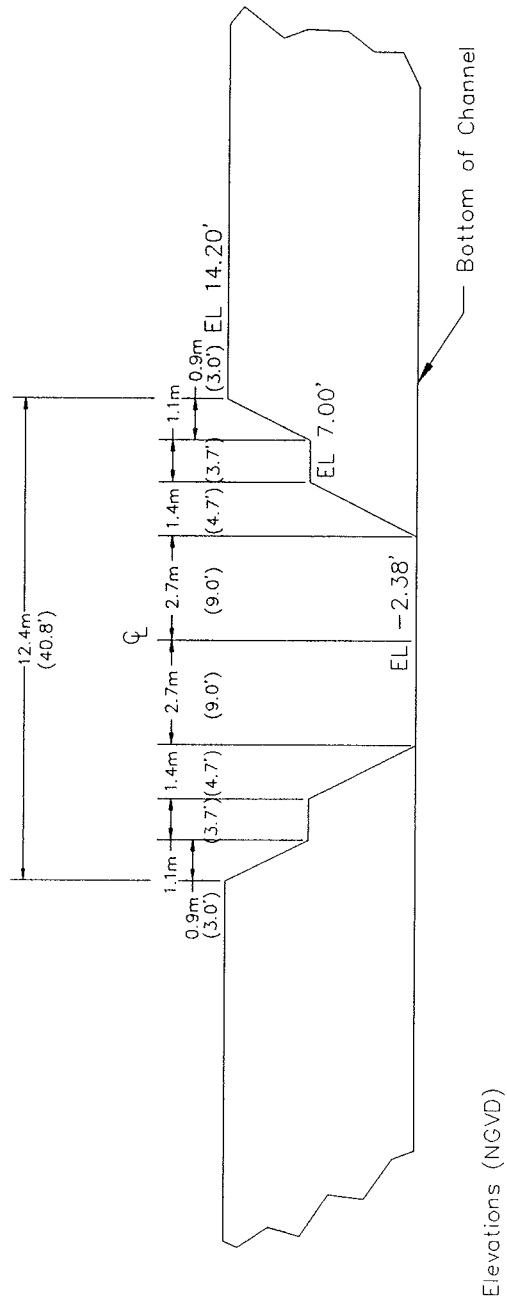
NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048



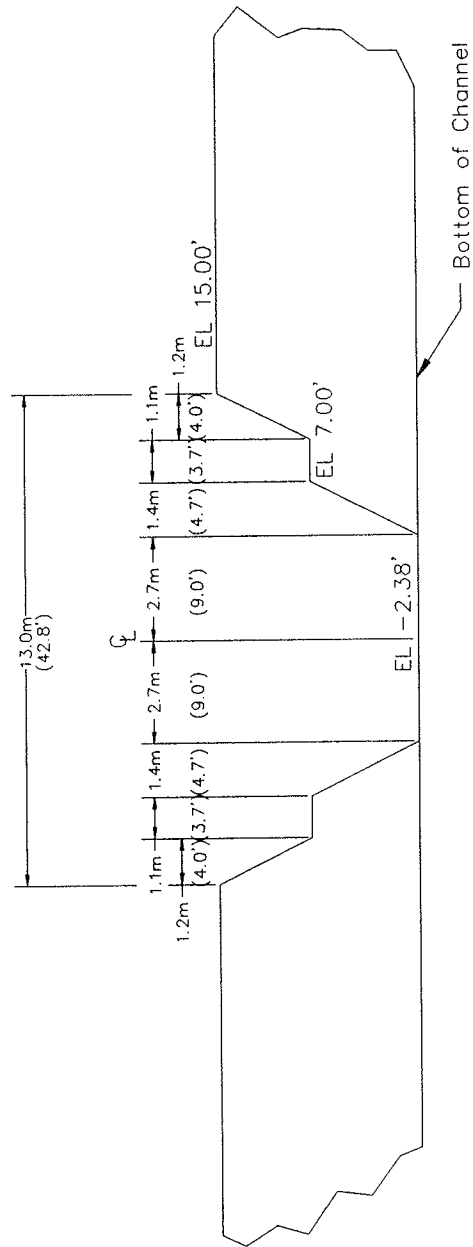
NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048



TYPE 2 WEIR DESIGN



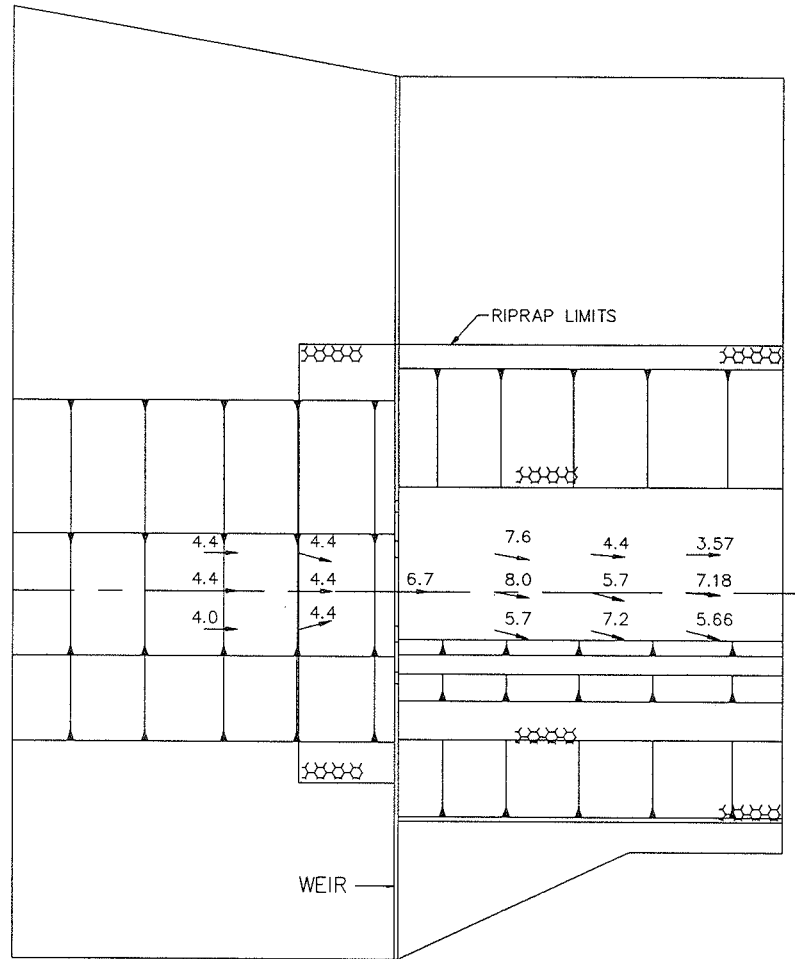
TYPE 3 WEIR DESIGN



Elevations (NGVD)

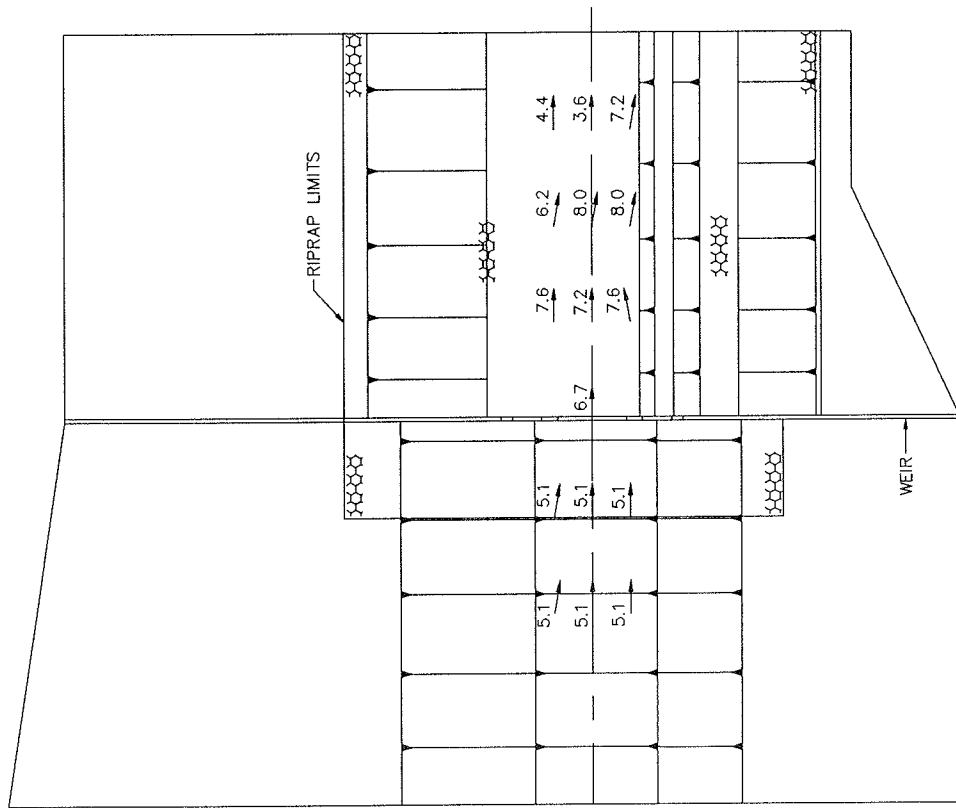
TYPE 4 WEIR DESIGN





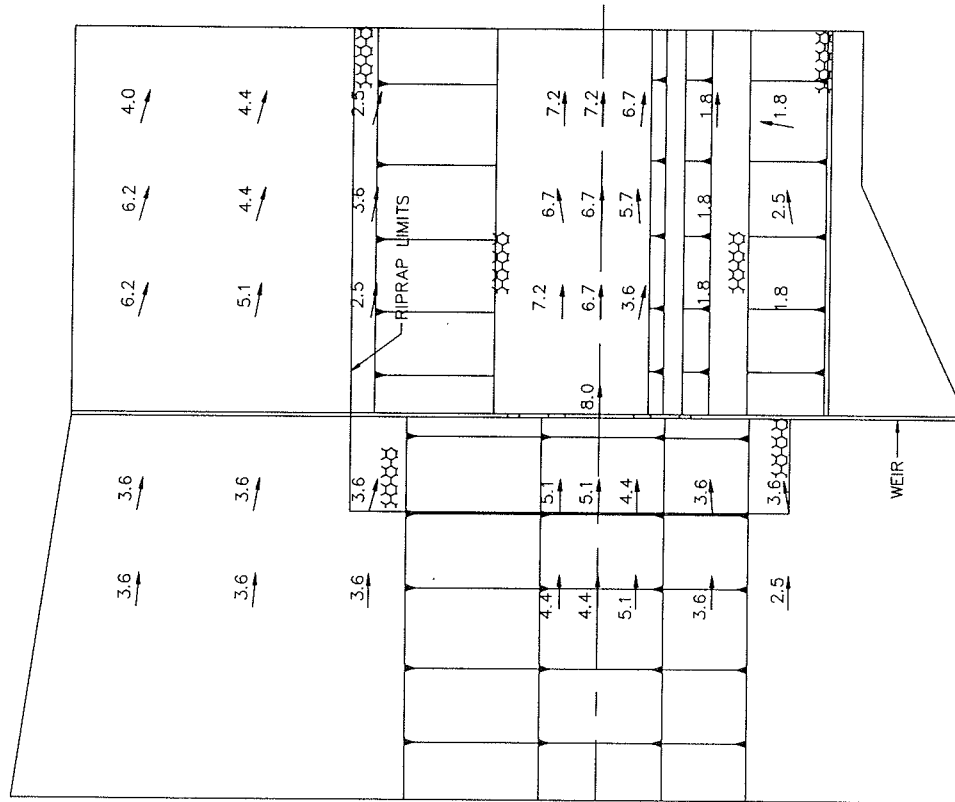
NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

TYPE 4 WEIR DESIGN  
TYPE 2 RIPRAP DESIGN  
2 YEAR EVENT



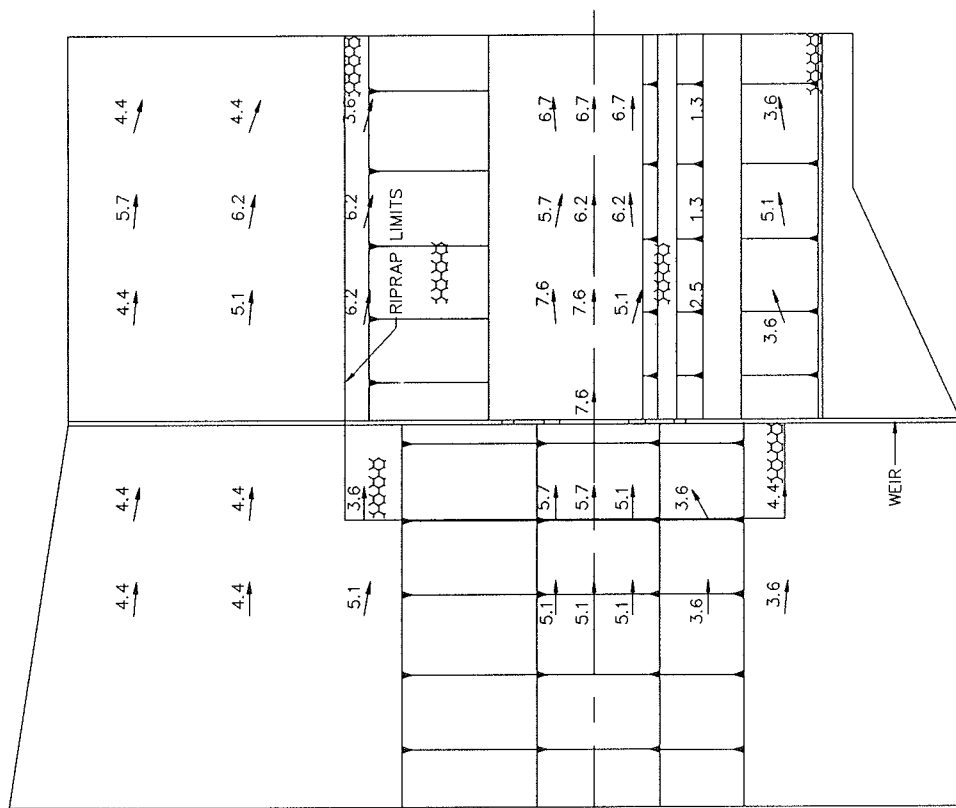
TYPE 4 WEIR DESIGN  
 TYPE 2 RIPRAP DESIGN  
 10 YEAR EVENT

NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048



TYPE 4 WEIR DESIGN  
TYPE 2 RIPRAP DESIGN  
40 YEAR EVENT

NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048



TYPE 4 WEIR DESIGN  
 TYPE 2 RIPRAP DESIGN  
 100 YEAR EVENT

NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE August 1996		3. REPORT TYPE AND DATES COVERED Final report
4. TITLE AND SUBTITLE Petaluma River, Channel Constriction Project, Sonoma County, California			5. FUNDING NUMBERS	
6. AUTHOR(S) Billy D. Fuller				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road, Vicksburg, MS 39180-6199			8. PERFORMING ORGANIZATION REPORT NUMBER Technical Report HL-96-6	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Engineer District, San Francisco 211 Main Street San Francisco, CA 94105-1905			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) <p>The model study was conducted to validate the preliminary design of the constriction weir, to modify the weir dimensions as necessary to provide the desired upstream water-surface elevations, and to determine if the riprap protection blanket was adequately sized.</p> <p>The 1:10-scale model indicated the need for extending the riprap blanket downstream from the weir to ensure protection of the streambed inside the reach of the modeled area. It was also necessary to modify the constriction weir to achieve the desired upstream water-surface elevations and erosion protection.</p> <p>For the flow conditions tested, the riprap blanket and constriction weir design presented will provide erosion protection.</p>				
14. SUBJECT TERMS Channel improvement      Petaluma Constriction weir      Riprap			15. NUMBER OF PAGES 48	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	